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THE GEOLOGY OF THE NOWA NOWA—SOUTH BUCHAN AREA, VICTORIA

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Abstract

An area of Palaeozoic rocks in East Gippsland between Nowa Nowa and South Buchan has been examined. The distribution of porphyroids, developed by shearing movements at the junction of Lower Devonian lavas and tuffs and the Upper Ordovician basement rocks, has been mapped in detail. There are also indications of faulting of lavas up against the basal sedimentary series. Tuffaceous sandstones including fossiliferous types occur interbedded with the volcanic rocks. The features of a small granitoid complex are described and the general relationships of the igneous rocks are discussed.

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Introduction

The object of this research has been the geological mapping and petrological study of an area of Palaeozoic rocks lying between the townships of Nowa Nowa and Buchan, with special reference to the Lower Devonian lavas and porphyroids, the latter term being used to describe schistose lavas and tuffs. The area covers the parishes of Nowa Nowa, Nowa Nowa South, and portions of Buchan and Tyldesley West. A considerable part of the southern parishes is covered by Cainozoic deposits, described by E. O. Teale (1920) as 'fluviatile sands, clays and gravels overlying Lower Cainozoic marine beds in the south.' No attempt was made to study this series in greater detail. A geological sketch-map has been prepared based on the boundaries shown by Teale and embodying certain alterations and additions by the authors. Where geological boundaries on the map have been traced, they are marked with full lines; broken lines indicate inferred boundaries. Two key areas were mapped in detail, namely, the area bounded by Boggy Creek, the Bruthen and Buchan Roads, and a smaller area between the southern extremity of the limestones and Mt. Tara. In other areas, examination has been limited to reconnaissance, combined with running some detailed traverses to establish the succession. The belt of Lower Devonian extending south from Mt. Tara has been treated in this way. This strip will be referred to as the Hospital Creek area.

The porphyroids of Lower Boggy Creek and Ironstone Creek, Nowa Nowa, constitute a distinct structural unit which has been named the Boggy Creek Group, and will be mentioned later in the discussion on porphyroids and the structure of the area.

To assist in the description of certain areas, it has been also necessary to name certain creeks; viz., Junction, Grap and Tomato Creeks in the south, and Granite, Crohn and Falls Creeks in the north.

Topography

The forest-covered slopes and foothills of the Tara Range dominate the topography. The Tertiary areas are lower-lying and more lightly timbered, the only cleared country being that on the limestones in the North. Timber tracks provide access to some of the ranges, but in many parts only the creeks afford reliable outcrops for detailed study.

Mt. Tara (1930 ft.) in the north, and Mt. Nowa Nowa (1100 ft.) in the south, are the most important peaks in the range, which trends NNE-SSW. The direction of drainage as determined by this water-shed is west to Boggy Creek and Yellow Water Holes Creek, east to Hospital Creek, and north to the Buchan River. In the south, Lake Tyers winds through the coastal plain from Nowa Nowa to the sea. At the township itself, it receives the waters of Boggy Creek, which has cut a deep gorge in the rocks of the volcanic series, providing good exposures.

Previous Work

The extensive volcanic series of which Nowa Nowa marks the southernmost extension was first described by A. W. Howitt (1876). He regarded the series as Lower Devonian, underlying the Middle Devonian limestone at

Buchan and unconformably overlying (?)Silurian limestones and slates at Limestone River. He recognized two broad classes of rocks in the series—one consisting of great accumulations of felstones, lavas and ashes, the other of massive porphyritic rocks. The latter were considered to be the stumps of extinct volcanoes, these old volcanic sites being represented now by Mt. Nowa Nowa, Mt. Tara and the higher peaks to the north. He noted the contact between the Snowy River Porphyries and Lower Palaeozoic in Lower Boggy Creek and described the ' felsite ' in the creek and porphyritic rocks from Tara Range.

E. J. Dunn (1907A) recognized cherts and diabases in Boggy Creek and cherts and jaspers in the Tara Range. These he interpreted as Cambrian (Heathcotian) in age. The first graptolites from this area were collected in 1908 by O. A. L. Whitelaw (1920), about six miles north of Nowa Nowa on the Buchan Road. These were described by T. S. Hall (1912) who fixed the age of the sedimentary rocks as Upper Ordovician. Graptolites were also found by W. H. Ferguson (1920) at several localities in the Tara Range. Ferguson also recorded plant remains in the 'porphyry-tuff' series at South Buchan and Mt. Murrendal, North Buchan, which he considered to be Lower Devonian in age.

The first detailed work carried out in the Nowa Nowa district was by E. O. Teale, who mapped the area between Nowa Nowa and South Buchan. The most important contributions he made may be summarized as follows :—

1. He showed the supposed Heathcotian charts to consist of chertified Ordovician slates, and the jaspers to be ' metasomatically altered igneous rocks.' Three additional graptolite localities were also discovered.
2. He recognized among the igneous rocks the following types, viz.,
   - Porphyroids.
   - Stratified ash beds.
   - Trachytic and andesitic rocks.
   - Acid porphyritic and pyroclastic rocks.
   - Keratophyres.
   - Granitic rocks.

His petrological work included analyses of two quartz-porphyrites and keratophyre ; using these he tentatively grouped the suite of rocks together with certain granites of Eastern Victoria into an acid-alkali province. Teale's work did not include the tracing of the individual rock types in the field, nor was any attempt made to explain the distribution and structural relationships of Devonian lavas and tuffs, and Ordovician sediments.

In a report on iron ore at Nowa Nowa, Whitelaw (1920) gave a sketch of the district showing a narrow belt marked Ordovician about half a mile north of Mt. Nowa Nowa, and running NW-SE. This had not been recorded on Teale's map. Whitelaw also indicated the presence of mollusca at his graptolite locality on the Buchan Road, but did not state the forms occurring there.

Correlation of Rock Types

The area contains extensive outcrops of Palaeozoic sedimentary rocks. Many of these are of proved Upper Ordovician age, as indicated by the presence of graptolites. Sandstones and cherts, however, occur interbedded with lavas and tuffs of the Snowy River Series, and along Junction Creek, east of Mt. Nowa Nowa there is an alternation of sandstones, shales, rhyodacites and tuffs which indicates contemporaneous deposition.

Where conclusive evidence regarding age is lacking, owing to the absence of fossils or of any distinctive lithology, stratigraphical correlation is uncertain. In many instances, rocks containing quartz veinlets have been tentatively correlated with the Upper Ordovician.

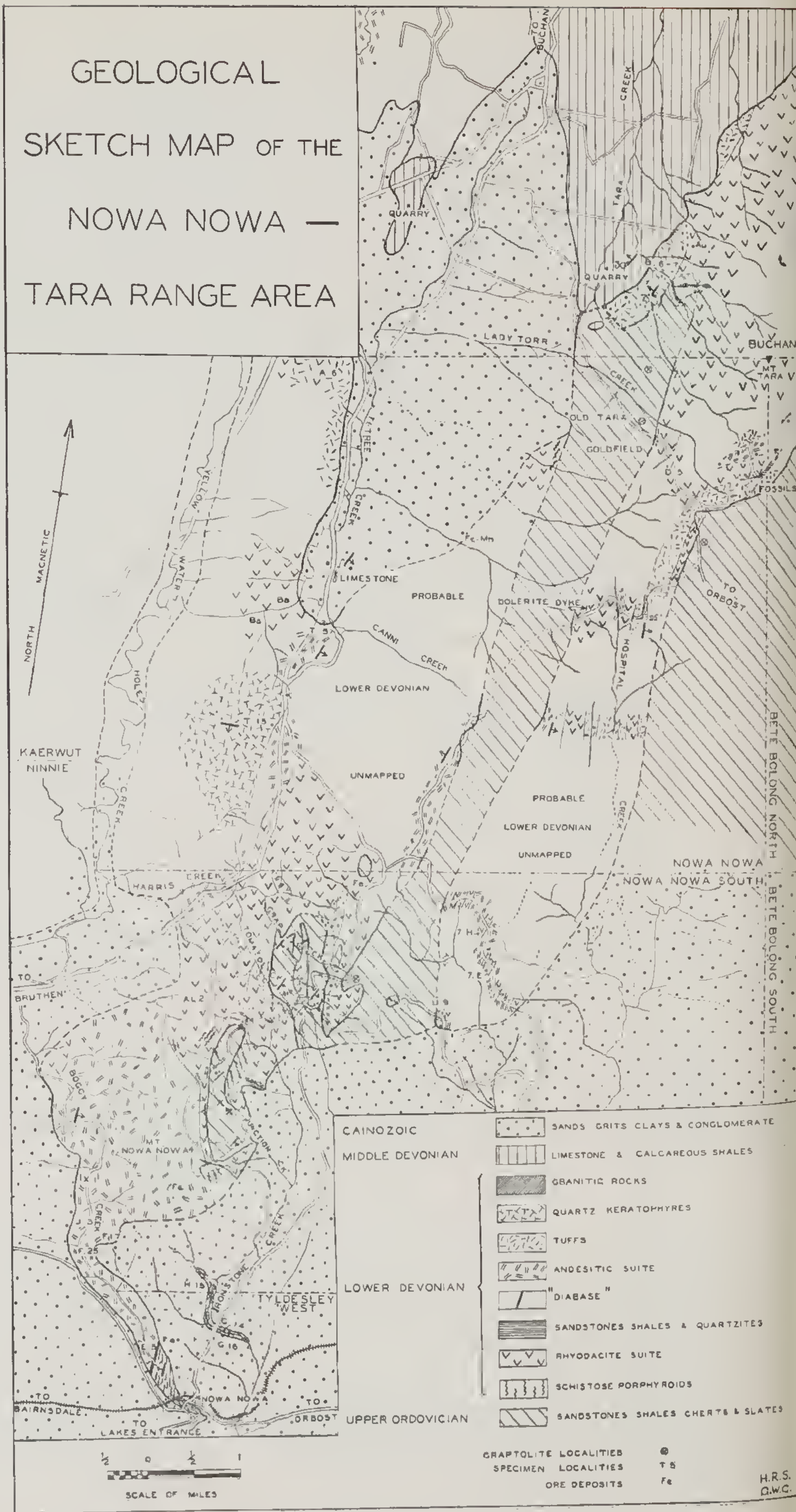

Fig. 1. Geological Sketch Map of the Nowa Nowa-Tara Range Area.

General Geology

Upper Ordovician

There are two main exposures of Upper Ordovician sediments in the area. One extends from about half a mile east of Hospital Creek into the County of Croajingalong; the other extends as a belt from west of Mt. Tara, nine miles south towards Nowa Nowa, averaging about a mile in width and following the major trend-line of the area. Minor occurrences are found as small inliers at four localities, viz. Lower Boggy Creek at the township of Nowa Nowa, Ironstone Creek, Grap Creek west of the Buchan road, and half a mile to the north near the road. Teale has also recorded an outcrop in Boggy Creek west of Mt. Nowa Nowa.

The lithology is varied. In the Tara Range, the rocks consist chiefly of micaceous sandstones, shales and cherts; cherty breccias and sheared sandstones also occur, and just east of the Buchan road are dark blue mudstones containing poorly-preserved graptolites. At the extreme North of the Tara Range belt Teale obtained graptolites in light-coloured cherty rocks, thus disproving the existence of the supposed Heathcotian in this area, as suggested by Dunn (1907). It is of interest, however, to note the rock types in the Nowa Nowa-Mt. Tara area which are suggestive of a Heathcotian lithology. The assemblage consists of diabase, red jaspers, cherts, and soda-rich igneous types.

In Grap Creek, fossiliferous black slates predominate, and in Boggy and Ironstone Creeks, where the rocks have been subjected to compression and recrystallization, contorted quartzites, chloritic shales and slates are represented. Near the contacts with granitic rocks in the Tara Range and Bete Bolong there is a local development of hornfels and quartzite.

Teale's examination of the Mt. Tara goldfield revealed the existence of numerous faults all striking roughly N10°E. He refers to the strata as being 'very much disturbed, altered and sheared'. This view is supported by abnormal local variation in strikes and dips, the occurrence of cleaved and shattered cherts, and brecciation.

Throughout the area the Ordovician rocks are intersected by quartz reefs and veinlets, which in the shatter zones occupy shearing planes, tension gashes and joints. In the old goldfields, auriferous reefs are associated with faults.

Graptolites have been found in black slates, cherts and shales, the various fossiliferous localities being shown on the general map. Hall (1912) also recorded brachiopods in two specimens collected by Whitelaw, six miles north of Nowa Nowa. An additional graptolite locality was found by the authors in Grap Creek. The graptolites occur there as whitish impressions in an indurated black shale. Owing to compression, it is difficult to make out the form of the thecae with any certainty, but Dr. D. E. Thomas has kindly identified the following forms:

Climacograptus caudatus Lapw.
Climacograptus brevis E. and W.
Climacograptus bicornis Hall.
Diplograptus (*Orthog.*) cf. *truncatus* var. *pauperatus* Lapw.
Diplograptus (*Orthog.*) cf. *truncatus* var. *intermedius* E. and W.
Diplograptus spp.
Dicranograptus clingani Carr
Dicellograptus pumilus Lapw.
Dicellograptus cf. *forchammeri* var. *flexuosus* Lapw.

He states that the association is typical of the zone of *Dicranograptus clingani* of the Eastonian subdivision of the Upper Ordovician.

Lower Devonian

The Lower Devonian cycle of igneous activity resulted in the eruption of acid to intermediate lavas and associated pyroclastics over the Upper Ordovician land surface, followed closely by minor granitic intrusions. Preceding the initial extrusions and during breaks in vulcanicity, there developed local basins of deposition in which sediments were laid down. The resulting sandstones and shales are in places tuffaceous in nature. No definite indication of the age of this series has yet been discovered. From a thin sandstone bed on Mt. Tara, which is interbedded with massive rhyodacites and ash-beds, the authors have collected marine fossils including *Spirifer*. When identified, these may provide the information necessary to fix the age. At Spring Creek, Buchan, Middle Devonian limestones follow conformably on the ash-beds which mark the top of the igneous series, indicating there was no great time interval separating the final pyroclastic stages and the onset of Middle Devonian marine sedimentation.

The Lower Devonian igneous rocks have previously been referred to, notably by Howitt and Teale, as the 'Snowy River Porphyries.' The name is misleading in that it implies a hypabyssal origin for the rocks of the series, and it would be better to adopt the more non-committal term, 'Snowy River Series,' as proposed by A. J. Gaskin (1943). According to Howitt the series extends north from Nowa Nowa into New South Wales. Generally it is from 2000 ft. to 2500 ft. in thickness, and attains a maximum at peaks such as Mt. Cobberas (6,025 ft.) and Black Mountain. Howitt, the only worker who has conducted an extensive survey of the series in Victoria, concluded that the lower part consisted mainly of massive acid lava flows which became more fragmental on ascending and merged into ashes, agglomerates and felstones. In the Buchan-Nowa Nowa area, though the general sequence of massive lavas followed by a pyroclastic phase is found, individual flows, when traced in the field, are in many cases of limited extent, and in places the various volcanic rock types alternate in rapid succession. This is well illustrated in the Hospital Creek area, where several traverses made across the belt of Lower Devonian revealed a different sequence in each case, as can be seen from the general map. A wider range of volcanic rocks than that described by Howitt has been observed, but the conglomerates which he found marking the passage into the Middle Devonian limestones are not represented in the area.

Volcanic Rocks

Rhyodacite Suite. Acid volcanic rocks are the most prevalent types belonging to the Devonian igneous series. They are widespread in the Tara Range and extend almost to Mt. Nowa Nowa. The rocks are extremely variable in colour but due to extensive silicification, they have generally resisted weathering better than most other rocks. They are typically massive, vesicles and flow structure being uncommon. Columnar jointing was noted at one locality in Harris Creek. By means of these features a number of strikes and dips were determined, but in general such indications are very difficult to obtain, and are probably not entirely reliable.

Macroscopically the rocks show phenocrysts of quartz, felspars and sometimes ferromagnesian minerals in a fine grained groundmass. In thin section large phenocrysts of quartz are almost always seen, commonly rounded and embayed. Both monoclinic and triclinic felspars occur as phenocrysts, the latter generally being more abundant. The plagioclase ranges from oligoclase to sodic andesine. Teale (1920) suggested that anorthoclase may be present in addition but none has been observed in our slides. Chlorite and bleached mica also occur and, rarely, remnants of amphibole. The groundmass is normally micro-crystalline, often a devitrified glass and often contains small inclusions of sedimentary and extrusive rocks.

These rocks were examined by Howitt (1876) who considered the volcanic rocks were extruded from vents occurring along meridional fissures. He named them quartz porphyries and regarded them as having solidified in old fissures and vents and therefore to be in part hypabyssal. Teale has pointed out, from his own investigations and a re-examination of Howitt's sections, that plagioclase is the dominant felspar and the rocks should therefore be named quartz porphyrites. The authors' findings are generally in agreement with those of Teale, namely, that plagioclase is normally in excess of orthoclase, though rarely the reverse is true. Moreover in several rocks quartz is subordinate, these representing gradational types to the andesites.

It is desirable to give these rocks a more exact name than quartz porphyrite; one which will indicate their volcanic origin and mineral composition. Gaskin (1943) when describing similar rocks from Bindi, has pointed out that they are of the rhyodacite type, corresponding to dellenite as described by Brögger. The chemical composition of two specimens of quartz porphyrites analysed by Teale are close to that of the average of sodaclase-granodiorite, given by Johannsen (1932). However Johannsen gives no example of the volcanie equivalent, which he names sodaclase rhyodacite. Moreover sodaclase is a name given by him (1931) to the end member of the plagioclase series at the sodic end—it is intended to replace the term albite, which he reserves for the mineral, $Na_2O.Al_2O_3.6SiO_2$. The term sodaclase is not, however, generally accepted, and since the plagioclase is oligoclase to sodic andesine in composition, the most suitable name for the volcanic rock is 'oligoclase rhyodacite.'

D5 is the typical rhyodacite of the Tara Range. Macroscopically it is dark red, medium grained, porphyritic, silicified rock, containing phenocrysts of quartz and orange felspar, and aggregations of green minerals. In thin section (6316), there are slightly more felspar phenocrysts than quartz. Quartz is present as large crystals, which are usually embayed and corroded. The plagioclase felspars are mostly oligoclase, orthoclase being comparatively rare. Both felspars have been extensively altered to sericite.

Pleochroic dark to light green biotite flakes are present but mainly the early biotite has broken down into chlorite, muscovite and sphene. The sphene occurs as small euhedral crystals within pseudomorphous aggregates of the other two minerals after biotite. Zircon, hematite, ilmenite, limonite and anatase (?) constitute the accessory minerals. The groundmass is devitrified and in part shows flow structure and contains an inclusion of red material. Rocks of this type frequently appear to be almost lacking in orthoclase phenocrysts; in such cases most of the potash indicated by chemical analyses is probably contained partly in the groundmass, and partly in the plagioclase crystals.

D 15 from a nearby locality is similar but microscopically (6312) it shows a development of calcite as an alteration of felspars. It also contains an inclusion of red material which contains small euhedral lath-shaped orthoclase crystals.

Q 19 from Falls Creek closely resembles a hornblende dacite. In thin section (6417), the plagioclase is sodic andesine and there are several six-sided hornblende crystals which have largely altered to chlorite. Some of the quartz crystals are surrounded by a corona of a very fine intergrowth of quartz and felspar crystals. This is probably due to late-stage attack by the residual magmatic liquors on the quartz, involving solution of quartz and deposition of felspar.

In AL 2 (6459), from about 3 miles north of Mt. Nowa Nowa, the same feature is seen on a larger scale. Plagioclase occurs veining the borders of quartz phenocrysts. The refractive index of this felspar is lower than that in previous sections and so the mineral is probably albite, formed by the attack of water and Na_2O rich solutions at a late stage.

In 7H (6471), which outcrops for a short distance along the Forestry Road east of the Tara Range, oligoclase is the dominant felspar and in excess of quartz, so this rock is probably a normal dacite. One large oligoclase crystal in the section is different from the others. It shows fine twinning with an antiperthitic development of orthoclase and quartz occurring as a regular pattern of small veins. This is probably an exsolution feature due to excess silica and potash in the original crystal at high temperature being thrown out during cooling.

A specimen from an adjacent band shows in thin section (6469) small fragments of oligoclase and quartz in a very fine grained glassy groundmass. Evidently soon after phenocrysts of these minerals developed, stresses occurred which shattered the early formed minerals and the sudden cooling chilled the groundmass. E. S. Hills (1929) noted the same feature in a rhyolite at Taggerty and suggested it may have been caused by the lava being suddenly chilled under water.

A feature of some of the rhyodacites is the development of secondary amphibole at the expense of earlier ferromagnesian minerals. More rarely epidote has been produced by deuteric alteration of primary amphibole. This is well shown in U 9 (6452), where granular aggregates of epidote have completely replaced the original mineral, although perfect outlines of primary pyroxenes and amphiboles are still preserved.

Porphyroids. According to Teall (1888), the term porphyroid was originally applied on the Continent to felsites of all kinds which have become more or less schistose in consequence of dynamic metamorphism and in which secondary micaceous minerals, especially sericite, have been developed. The term had apparently been used for such rocks by de la Vallée Poussin and Renard (1884) in the Ardennes and by H. Loretz (1882) in the Thüringerwald. Teall found similar rocks in North Wales, where basic igneous rocks locally became schistose and passed into chloritic schists and acid rocks sometimes developed into sericitic schists. More recently C. Rice (1941) has defined porphyroid as a term applied to porphyroblastic metamorphic rocks intermediate structurally between hälleflinta and granite-gneiss, in the same way as quartz porphyry and granite-porphyry are intermediate between rhyolite and granite. He also mentions that the term has been extended to include porphyroblastic schists of sedimentary origin. C. Schmidt (1928) simply describes the rock as the 'infolge von Dynamometamorphose geschieferter Porphyr.' The authors have followed Teall's usage of the word and extended it to include all extrusive and pyroclastic rocks of the Boggy Creek, which show the effects of the intense shearing. Rocks of this series show considerable variation in the abundance of quartz phenocrysts, and often the sheared rocks are obviously fragmental in origin (Plate IX, Fig. 2). In some cases it is not possible to state the original nature of the rock type, whether it be an intercalated acid flow or an ash bed.

The description of porphyroids from Boggy Creek given by Teale (1920) represents the only recorded occurrence of these rocks in Victoria. Localities at which these porphyroids have been recognized are as follows :

(i) Boggy and Ironstone Creeks, railway cutting west of Boggy Creek.
(ii) Mt. Nowa Nowa area at the contact with Devonian sedimentary rocks. In this area gradations to unsheared rhyodacites have been traced.
(iii) Tomato Creek

(iv) Tara Range.
  a. Along the Ordovician contacts.
  b. Gunn's Mine.
  c. Other minor occurrences.

Specimens from all these localities show a general similarity in thin section. In the more quartzose varieties augenstructures are well developed and the quartz phenocrysts are typically fractured and corroded. The sericite characteristically occurs as stringers veining and surrounding residual felspars, if the latter are not entirely obliterated. Typical examples are afforded by thin sections (6331), (6377), (6374), (6335) (Plate XI, Fig. 4).

Andesitic Suite. Teale (1920) described the following more basic rock types from Boggy Creek—altered augite andesite, altered andesite ash and altered trachyte (or trachytic andesite), stating that these rocks occur in definite bands. Further investigation has revealed andesitic rocks in a number of other localities. The largest outcrop in the area is found on the western slopes of Mt. Nowa Nowa and extending to the Boggy Creek gorge, where thicknesses of over 100 feet are exposed. Other exposures occur along the Bruthen road, near Canni Creek and east to the main divide, along the Forestry road on the east side of the range, in the north-west corner of the area, at various localities in the Grap Creek area, the Hospital Creek area and in the north Tara Range. In the latter region the andesitic rocks are in small amount compared with the prevalent acid flows.

The pyroclastic types, which are limited to the area between Mt. Nowa Nowa and Boggy Creek and to minor occurrences on the eastern side of Tara Range, are described later under the heading 'Ash Beds.' Of the effusives, the great majority show some free quartz in thin section, generally as small phenocrysts which constitute less than one-twentieth of the total leucocratic minerals. According to Johannsen (1937), these rocks should therefore be classified as quartz andesites. Several specimens, in which no free quartz is discernible in thin section, represent true andesites, whilst others, in which the amount of quartz approaches that of felspar, are transitional types to dacites or rhyodacites. However there is a clear-cut distinction between the quartz-andesites, having no visible quartz but fairly abundant ferromagnesian minerals, and the rhyodacites, with abundant large quartz phenocrysts, which is born out by the large differences in the silica percentages shown in the chemical analyses of the rocks (see Table 1). The contrast is quite apparent in the field and gradational types are comparatively rare. In the Mt. Nowa Nowa area, andesites overlie rhyodacites, but along the Bruthen Road, where inclusions of andesite in rhyodacite are found, and in the Mt. Tara area, alternation of flows of the two rock types is indicated.

The base of the main andesite mass occurs in the Boggy Creek gorge, about two-thirds of a mile above Nowa Nowa township. Separating the Boggy Creek porphyroid beds on the east from the interbedded massive and fragmental andesites and trachy-andesites on the west is an outcrop about two chains wide of a greenish rock, which because of its distinctive appearance is referred to as diabase. Going west, a succession can be traced from sheared purplish shale through sheared diabase ash of varying grain-size, the coarser types showing a marked schistosity, to a more massive diabase which exhibits porphyroid structure in thin section, and finally to the massive green unsheared diabase, with strongly developed jointing. Immediately overlying the diabase the suceeeding andesites are rather more basic than usual and slightly schistose in appearance ; these are overlain in turn by normal andesites and ash beds.

It would appear that the thinly-bedded tuffs, etc. of the Boggy Creek series and the basal flows and tuffs of the andesite suite have been subjected to the same shearing stresses. The former series was converted to schistose porphyroids, but the effect on the more resistant andesites was less marked, the dense massive diabase in particular being apparently unaffected.

The diabase is green in colour, and extremely hard and tough. It is for the most part aphanitic, but occasional dark minerals are visible as phenocrysts. In thin section (6361) the rock is seen to consist of idiomorphic augite, often altered to almost isotropic clinochlore and iron oxides, andesine and a very small amount of quartz. Epidote, carbonates, kaolin and sericite may partly or wholly replace felspar; epidote also occurs in veins. Accessories include leucoxene, associated with titaniferous iron ore, and apatite (Plate XI, Fig. 1). The replacing sericite appears as brighly polarizing fibres, or more often as plates which approach muscovite in character, and are confined to the altered felspars. The mode of occurrence of the sericite differs from that produced by regional metamorphism as seen in the porphyroids, which are characterized by the presence of roughly parallel stringers of fine sericite extending through phenocrysts and groundmass. The replacing sericite plates probably resulted from the action of aqueous solutions. Since soda-lime felspars predominate, the requisite potash may have been derived from potash felspar held in solid solution or more likely, from circulating waters of hydrothermal origin.

Though its distinctive dense tough texture and green colour give this rock a similar appearance to the Heathcotian diabase it is actually the basal flow of the andesites. It is the most basic igneous rock found in the Snowy River Series and is the only type containing unaltered pyroxene.

Red jaspers are associated with diabase, andesites and andesite ash at a number of localities south of Mt. Nowa Nowa. The jaspers are invariably accompanied by specular hematite, often manganiferous, colloform quartz and small amounts of pyrite. Field evidence suggests that hydrothermal solutions, bringing in the hematite and quartz, converted adjacent rocks to jaspers, and in the case of the diabase may also have resulted in the development of chlorite, calcite and epidote.

In general, the rocks for about a mile above the diabase of Boggy Creek are even-grained and show trachytic structure, whilst further north they become more porphyritic, with a finer-grained and sometimes glassy groundmass. Both types are characterized by original ferromagnesian minerals having almost completely broken down to chlorite and secondary amphiboles, probably due to deuteric reactions.

E 5 is a typical altered quartz andesite from Lower Boggy Creek and has been selected for chemical analysis. It is a dark grey, fine grained rock with pink felspar phenocrysts. In thin section (6317) it shows phenocrysts of plagioclase, chloritic aggregates associated with magnetite representing altered femic minerals, and occasionally quartz. The groundmass contains small felspar laths, showing trachytic structure. The larger felspars are usually cloudy, due to kaolinization, although some show fresh rims. They show twin lamellae on which extinction angles range up to 10°, indicating oligoclase to sodic andesine. Chloritic pseudomorphs frequently occur with outlines suggestive of pyroxene. Magnetite has usually been thrown out to the edges of the chlorite flakes which occasionally contain small crystals of sphene. An example of the trachyandesite type (6486) shows rare porphyritic oligoclase in an even-grained matrix of sanidine laths with well-marked flow-structure.

Specimen F 25, from further up Boggy Creek, is a green rock which is traversed by veinlets consisting of quartz, albite and radiating groups of clinochlore needles. The plagioclase phenocrysts in this case are andesine. In the main portion of the slide (6329), pennine is found replacing original femic minerals, but the clinochlore is probably a primary mineral in the late-stage crystallate. Clinochlore is seen cutting pennine aggregates and is also scattered in small flakes throughout the section. Zircons also occur, some having pleochroic haloes.

A thin section of a rock from Boggy Creek west of Mt. Nowa Nowa (6455) shows green radiating fibres of secondary amphibole which are often associated with plagioclase and probably formed by deuteric reactions—the plagioclase supplying the lime and iron and magnesium coming from the primary pyroxenes or amphiboles.

The relative proportions of potash and soda-lime felspar vary in rocks from different parts of the area. The quartz-felspar ratio also varies. In an example from Granite Creek (6442), quartz phenocrysts, extensively corroded and fractured, are only slightly less abundant than the felspars. This rock approaches a rhyodacite type.

Rutile, apatite and anatase (?) have also been noted in thin sections of andesites. A heavy mineral analysis of quartz andesite from the Tara Range gave an index number of 0·11 and revealed the presence of blue anatase, yellow anatase, epidote, apatite, hematite, zoned and yellow zircons and sulphides.

Ash Beds. There are three main pyroclastic phases in the Snowy River Series, represented by the following rock types :—

1. Stratified ash beds, occurring in Lower Boggy Creek and Ironstone Creek.
2. Andesitic ash and fine chertified ash interbedded with massive andesites to the south and west of Mt. Nowa Nowa.
3. Acid tuffs and coarse fragmental beds immediately underlying limestones in the Buchan district.

Stratified Ash Beds : These rocks constitute the base of the Series at Nowa Nowa. They have all been subjected to shearing stresses, and in some cases converted to 'porphyroids'. They dip steeply and strike approximately N 10°E.

The rocks are extremely variable in colour and texture, ranging from very fine grained dense chertified tuffs and shales to coarse fragmental beds showing marked schistosity. One thin silicified ash bed, too silicified to develop schistosity, exhibits a series of miniature faults (Plate IX, Fig. 1). Except in the case of the more silicified rocks, alteration has invariably occurred with the formation of chlorite, micaceous material and secondary amphibole. The regularity of the stratification in some cases suggests sub-aqueous deposition (Plate XI, Fig. 2). The occurrence of ferruginous sandstone further supports this view. It is likely, however, that deposition was in the main sub-aerial because of the general lack of pronounced sorting in the beds.

H 15 is a typical specimen of the Boggy Creek beds. It is a purplish grey compact rock containing many small light coloured inclusions. The thin section (6343) shows some fractured quartz grains, altered felspars, chlorite, iron oxides, a chalcedonic fragment and lumps of pyroclastic material, containing small trachytic felspars. The felspars appear to be monoclinic and are contained in a devitrified ground mass. (Plate XI, Fig. 3).

K 3 is a light grey finely laminated tuffaceous shale from Boggy Creek near the contact with the andesites. In thin section, the stratification is marked by fine wisps of sericitic mica and subangular quartz grains. Patches of brown amorphous material are present together with zircon and rare secondary amphibole and scattered grains of iron ore.

Andesitic and Fine Chertified Ashes : Ash beds interbedded with massive andesites outcrop along the Boggy Creek Gorge and extend east to Mt. Nowa

Nowa. They weather to soft friable material and a chocolate brown soil. Essentially the same minerals as in andesite occur together with fragments of other rocks in a glassy matrix.

F 17 is a typical specimen of this series. It is a slightly sheared pink rock with pink felspars and aggregates of chlorite minerals. In thin section (6325) it shows crystals of pyroxene and amphibole which have altered to secondary amphibole and thrown out hematite along the crystal boundaries. Felspar phenocrysts are abundant, plagioclase (mostly oligoclase) being in excess of orthoclase, both being partly sericitized. Radiating groups of secondary amphibole crystals occur associated with plagioclase. Granulated quartz, hematite and occasional sphene crystals are also present. The groundmass contains chlorite, finely disseminated iron ore and glass.

J 3 is a reddish green cherty rock from the banks of Boggy Creek, south-west of Mt. Nowa Nowa. Similar cherts occur dipping under andesite ash beds in Boggy Creek about one mile south of the Bruthen Road bridge on Mt. Nowa Nowa and several other widely separated localities. In thin section (6353) it is seen to consist of mainly small angular quartz grains and occasional hematite and plagioclase grains with a number of larger yellowish brown hexagonal secondary ferromagnesian minerals.

Acid Tuffs : In the northern Tara Range and in the ranges west of Buchan, thick deposits of fine and coarsely fragmental acid pyroclastic rocks occur at the top of the Snowy River Series. As seen in Spring Creek, Buchan, they conformably underlie the Middle Devonian limestones. However at one locality about five miles SSW of Buchan, an ash-bed containing a limestone inclusion was found, indicating volcanic activity must have proceeded spasmodically into the Middle Devonian.

Granite Creek, in the north, provides excellent exposures of bedded pyroclastics, ranging from tuffaceous chocolate shales to coarse-grained acid fragmental types. The rocks strike NNE and dip steeply west at angles of from 70° to 80°. A thickness of about 1600 feet is represented. The overlying Middle Devonian limestones dip west at much lower angles, from 40° to 45°.

B 6 and B 7 are fragmental rocks from north-east of the Buchan Marble Quarry near the boundary of the limestone. They are both heterogeneous purple rocks with green streaks and containing inclusions of purple shale and other light pink and orange fragments. Both are somewhat sheared and have thin films of pyrolusite deposited on fracture surfaces. Under the microscope (6304), B 7 is seen to contain a piece of fine grained felspathic rock ; pieces of red opaque material containing small altered felspars, chlorite, a cluster of secondary amphibole needles and limonite.

B 6 (6303) contains mainly fragments of andesite in various stages of alteration and pieces of red glassy material. Some andesite fragments consist of plagioclase phenocrysts and secondary amphiboles, pseudomorphous after augite phenocrysts in a groundmass of glass and plagioclase laths showing flow structure. Occasionally there is a development of epidote due to alteration of felspar. In some places secondary amphiboles occur in large clusters completely replacing the original fragment. Pieces of red glassy material containing occasional plagioclase phenocrysts probably represent chilled portions of earlier extruded magma.

A 6 is a typical acid ash bed. Macroscopically it has a purple matrix containing phenocrysts of quartz and felspars with wide pink silicified bands. The thin section (6301) shows abundant angular quartz crystals with rarer plagioclase (oligoclase-andesine) and orthoclase and fragments of fine-grained chalcedonic material, which may represent inclusions of a fine-grained siliceous rock but are more probably formed by secondary silicification. The groundmass is red due to an abundance of finely disseminated hematite grains.

Quartz Keratophyres. In a tributary of Hospital creek, Teale collected a medium grained porphyritic rock which on analysis showed a silica percentage comparable with that of the normal rhyodacites, but a higher soda-potash ratio. This rock was similar mineralogically and chemically to a specimen collected by Howitt at Noyang and which Skeats (1909) named quartz keratophyre. It was characterized by phenocrysts of oligoclase, corroded quartz and chloritic pseudomorphs in a microcrystalline ground mass of quartz and felspar.

Further occurrences of this rock type have been found in other parts of the area. The largest of these extends for over a square mile in an area west of the junction between the Buchan and Bruthen Roads. Small outcrops also occur along the Forestry Road on the east side of the Tara Range and in Ironstone Creek. Partial chemical analyses were carried out on several specimens to support their identification.

Age relations with the other volcanic rocks are not clear. Teale deduced that the keratophyres were younger than the earliest sheared members of the Snowy River Series, but this interpretation was based on a single outcrop which in itself cannot be regarded as conclusive. The keratophyres west of the Bruthen Road, which are leached white, show strongly marked flow structure, striking east-west and dipping at a high angle south. This is in sharp contrast to the prevailing strikes in the Nowa Nowa-Buchan area, which are generally east of north. Along the Forestry Road the keratophyres are associated with quartz-andesites and rhyodacites and strike N10°E. The Ironstone Creek keratophyre is apparently interbedded with the oldest schistose members of the volcanic series. The edges of the band in contact with the porphyroids are sheared, whereas the middle remains unaltered. This may indicate that the keratophyre is of the same age as the porphyroids but was more resistant to the shearing stresses, or that it was intruded as a dyke and represents a late-stage soda-rich product of the magma, probably of the same age as the soda solutions which albitized the granite. This latter view is further supported by the occurrence of quartz-albite veinlets in an andesite in Boggy Creek.

T 15 from the Bruthen Road area is a typical keratophyre containing 6·9% Na_2O and practically no potash. The hand specimen is a hard white rock with occasional white felspar phenocrysts. The thin section (6451) shows phenocrysts of plagioclase, spherulitic growths of quartz, and occasional clusters of green secondary amphiboles in a finely crystalline ground mass of quartz and felspar. The plagioclase is a sodic oligoclase and some of the crystals which possess ragged edges have evidently reacted with a ground mass just prior to its solidification. T 12 is a white fine-grained laminated rock from a nearby locality which displays very marked flow structure and possibly represents a chilled phase of the keratophyre.

G 14 occurs in Ironstone Creek, about five chains below the Buchan Road bridge. It is a green porphyritic rock with phenocrysts of quartz and white felspar, the latter being in excess. It contains 4·55% Na_2O and 0·19% K_2O. In thin section (6333) there are phenocrysts of quartz and plagioclase, both being attacked by the groundmass. The plagioclase, which has a composition of about $Ab_{91}An_6$, shows broad albite twinning and contains numerous inclusions of quartz and groundmass. Limonite, secondary amphibole and chlorite are frequently found deposited along the frayed edges of quartz and albite phenocrysts. The groundmass is fine grained and holocrystalline, and consists mainly of quartz and a little felspar, with scattered chloritic remnants of ferromagnesian minerals and occasional sphene and zircon crystals. The sheared edges of the rock show a larger development of amphibole. A vein of quartz and albite traverses the section.

In 7 E (6468), plagioclase phenocrysts are greatly in excess of quartz. There are also segregations of smaller plagioclase laths, all the felspars being oligoclase. This rock is also probably a quartz keratophyre, although more calcic than the others described.

TABLE I.

	I	II	III	IV	V	VI	VII	VIII
SiO_2	61·20	72·55	73·41	60·33	72·41			
Al_2O_3	19·52	11·74	12·30	18·48	14·36			
Fe_2O_3	2·05	2·54	2·09	1·20	2·94			
FeO	2·88	0·46	2·13	3·83	0·85			
MgO	2·89	0·68	0·14	1·76	1·18			
CaO	1·34	1·85	1·08	4·74	0·87			
Na_2O	3·52	3·46	3·71	2·39	6·86	4·55	7·05	4·12
K_2O	3·72	4·41	4·04	3·98	0·13	0·13	0·18	1·69
H_2O—	1·16	0·41	1·51	1·39	0·67			
HO_2—	0·37	0·06	0·10	0·19	0·04			
CO_2	—	1·80	—	—				
TiO_2	0·76	0·175	0·16	0·48	0·26			
P_2O_5	0·24	0·14	Tr.	0·18	0·17			
MnO	0·13	—	—	0·12	0·09			
	99·78	100·27	100·67	99·17	100·85			

I. Quartz Syenite, Granite Creek, Tara Range. (Analyst : H. R. Samson)
II Rhyodacite, ½ mile S. of Mount Tara. (Analyst : E. O. Teale 1920)
III Rhyodacite, 3 miles NNE Mount Tara. (Analyst : E. O. Teale 1920)
IV Quartz Andesite, Boggy Creek, Nowa Nowa (Analyst : G. W. Cochrane)
V Quartz keratophyre, Bill's Creek, Nowa Nowa (Analyst : E. O. Teale 1920)

Alkali Analyses

VI Quartz keratophyre, Ironstone Creek, Nowa Nowa. (Analyst : H. R. Samson)
VII Quartz keratophyre, SW of Canni Creek (Analyst : H. R. S.)
VIII Soda Granite, Granite Creek, Tara Range (Analyst : H. R. S.)

GRANITOID ROCKS

Outcrops of granitoid rocks in the area are limited to the vicinity of two small creeks, about half a mile WNW of Mt. Lara and about 20 chains east of the limestone-ash contact. The main outcrop is about 30 chains long, although it is not continuous, the stream being crossed at one point by a narrow neck of 'rhyodacite' (or quartz-porphyrite) about two yards wide ; some six chains further east there is another smaller outcrop. The main rock type is a quartz syenite, but granitic and soda-rich varieties also occur.

Teale discovered this granitic outcrop, and from his field and petrological examinations of the rock concluded that it was a hornblende granite. He correlated it with similar rocks at Colquhoun and Bete Bolong, where the intrusive nature into Ordovician sediments could be seen. He included these granites in the group of Victorian alkali granites. Since the adjacent 'ash-beds' s oushowedigns of contact alteration, he presumed the granite to be the older.

Quartz Syenite. Macroscopically no quartz is visible, the rock consisting predominantly of felspar and hornblende. Pink orthoclase is in excess of pale-green oligoclase. These facts together with the low silica percentage shown by the chemical analysis given in Table 1, place the rock in the quartz syenite class.

In thin section (6406) the felspars are rarely found fresh, rendering accurate determination difficult, but the plagioclase is certainly a soda-rich variety, about oligoclase in composition. Both interstitial quartz and perthite occur in minor amounts. Hornblende is extensively altered to chlorite (pennine and clinochlore) and rarely to ilmenite and epidote, probably due to deuteric action. Sphene also occasionally occurs.

Soda Granites. The normal soda granite is pink in colour with occasional green patches of ferromagnesian mineral. In thin section (6444) it shows predominant quartz and cloudy orthoclase with lesser amounts of hornblende, which is being replaced by chlorite and epidote, and finely twinned plagioclase. Straight extinction in the latter indicates oligoclase.

S 6 is an albite-rich variety. It is a whitish coarse-grained rock, which in thin section (6435) is seen to consist mainly of orthoclase, sodic plagioclase (finely twinned oligoclase and chess-board albite) and quartz. The albite is generally found replacing quartz or intergrown with it and exhibiting graphic and granophyric structures (Plate X, Fig. 2). A similar texture is seen on a smaller scale in a quartz syenite adjacent to a rhyodacite. The syenite is cut by veinlets of finely crystalline albite, orthoclase and lobate quartz, with micrographic intergrowths in patches (6409). It would appear that replacement by soda-rich solutions was a feature of late-stage magmatic activity.

Aplite and Pegmatite. Cutting the syenite at one locality is an aplite vein consisting of a mosaic of orthoclase and quartz. This grades into a pegmatitic mass of a coarse pink felspar with occasional quartz crystals. Perthitic albite is developed in the pegmatite orthoclase, and is associated with chess-board albite (6432) (Plate X, Fig. 1) (6433).

Relation of Granitic Rocks to Ordovician

Teale shows that in the Bete Bolong area there has been a development of hornfels in the Ordovician along the contact with the granite. In one branch of Granite Creek, Tara Range, metamorphism of the Ordovician by syenite is seen. The contact rock is a granitized quartzite. The thin section (6437) shows that the original rounded quartz grains have been attacked and in the interstices secondary quartz, albite, amphibole, and orthoclase have been deposited. The amphibole has in part been replaced by pennine and clinochlore. Apatite is present and also a number of rounded zircons, which belonged probably to the original sedimentary rock. Albite generally shows some crystalline form and occurs bordering the original quartz grains. The orthoclase, however, is completely allotriomorphic, indicating soda was introduced before potash (Plate X, Fig. 3).

A lower grade of metamorphism is exhibited in a bed of hornfels further east, which contains very fine aggregates of sericite and chlorite fibres, as well as the original small quartz grains (6438).

Relation of Quartz Syenite to Rhyodacite

The rhyodacite often appears normal up to within a yard or so of the contact and no penetrations by offshoots from the intrusive plutonic rocks were noticed. A series of specimens was taken across the first contact. A very narrow zone of apparently basified quartz-syenite contains green inclusions of mainly fine chlorite and quartz possibly representing xenoliths of unreplaced rhyodacite (6410). This is succeeded by a structureless green rock in which all felspars are obliterated, a few small rounded quartz crystals with frayed cloudy borders remaining in a microcrystalline groundmass containing almost amorphous chloritic material (6411). In the next zone some felspars are preserved and quartz phenocrysts are larger (6412). The transition to normal rhyodacite is rapid, showing the typical large embayed quartz crystals, idiomorphic plagioclase, generally slightly sericitized, chlorite, and biotite which appears to replace original hornblende (6413).

There is no definite evidence of contact metamorphism by the syenite, indeed the textures of contact specimens are suggestive of a chilled rhyodacite border, and in the field a number of syenite inclusions in the (?) chilled rock were observed. These features, together with the occurrence of granitic rocks at a higher level upstream, and on a ridge to the north, suggest that the small neck of ' rhyodacite ' across the creek represents a dyke intrusion rather than a portion of unreplaced country rock.

Relation of Granite to Rhyodacite

Near one of the contacts, a boulder in the bed of the creek was found to exhibit the following succession of contact rock types : unaltered rhyodacite, followed by a greenish finer grained type having a streaked, rudely schistose appearance (schistose rhyodacite), a green hybrid rock showing schlieren and veinlets of quartz and felspar, and finally a granite with coarse quartz phenocrysts and more dark minerals than the normal variety.

This granite-rhyodacite contact shows different contact effects from the quartz syenite-rhyodacite contact described above. The ' schistose rhyodacite ' (6422) consists of rounded quartz crystals with cloudy borders, and fractured and carbonated felspars in a silicified structureless matrix. One felspar shows alteration to zoisite. In the ' veined hybrid rock ' (6446), composite grains of quartz, albite, and minor amounts of orthoclase and hornblende form veinlets in a matrix of altered rhyodacite, represented by fibrous chlorite and angular fragments of quartz and felspar (Plate IX Fig. 3).

In some specimens the rhyodacite has been converted to a coarser grained rock consisting of short prismatic felspars of both plagioclase and orthoclase, and occasional larger crystals of biotite and quartz (6418). This variety grades into one with the larger aggregates of quartz and felspar, which may form blebs in the hand specimen up to half an inch in diameter (6426). These constitute porphyroblasts originating from the intrusive magma. The reaction zone is marked by the development of a sericitic mica and fibrous green amphibole, both poorly crystallized, in which patches of granular quartz appear (6421) (Plate X, Fig. 4). Therefore the granite is intrusive into rhyodacite.

Relation of Granite to Quartz Syenite

Specimens were studied from the contact between granite and quartz syenite at the junction of Falls Creek and Granite Creek. There appears to have been an addition of quartz to the syenite ; the felspar is saussuritized and the hornblende completely broken down into pennine and clinochlore. The quartz sometimes is bordered with albite, and both quartz and albite in the groundmass seem to be attacking the felspar. Albite increases towards the granite and in this rock too, it is attacking the quartz (6429).

This is therefore no clear evidence of the age relationships of the two plutonic rocks, although from field evidence the occurrence of granite in dyke-like forms through the syenite suggests that the granite is the younger. This view is further supported by the fact that the aplite-pegmatite and several other narrow leucocratic veins, presumably the final product of the granitic magma, clearly intersect the quartz syenite.

Relative Age of the Rocks

From observations of the various rocks in this region, it is clear that the granitic complex is post-Upper Ordovician in age ; there is also evidence that the granite is post-Lower Devonian. However, the relationships of the quartz-syenite to the Lower Devonian lavas is not so distinct, one contact showing features which suggest intrusion of quartz-syenite by the porphyritic 'rhyodacite.' Definite evidence concerning the relations of quartz-syenite to the soda-granite is lacking.

Sedimentary Rocks

Teale suspected the existence of sub-aqueous deposition in the Boggy Creek beds but stated that . . . 'in the absence therefore of definitely aqueous sediments interbedded with ash-beds, or of the association of fossils in sedimentary material with the pyroclastics, it may not be possible to decide whether the beds in question are really sub-aqueous or not.' The presence of Devonian sedimentary rocks definitely associated with the volcanic and pyroclastic types has been shown by the authors in four distinct localities, Tara Range, Ironstone Creek, north of Mt. Nowa Nowa and Tomato Creek area.

The Tara Range Sandstones. On the top of the Tara Range, about half a mile south of Mt. Tara, a thin sandstone bed is interbedded with massive rhyodacite and ash-beds, and consists of a fossiliferous band about 6 in. wide, grading up through tuffaceous sands to true ash-beds. The same succession occurs along a ridge two miles to the south, though the fossiliferous bed is not represented, and the tuffaceous sandstones are more finely laminated.

Boggy Creek Group. Sedimentary rocks were found in this series at two localities. Shales and ferruginous sandstones are interbedded with ash-beds and porphyroids in Ironstone Creek, and further north a friable yellow sandstone is similarly associated. These fine-grained sediments show no trace of the shearing stresses which produced textural and mineralogical changes in the associated rock types in the same series.

Mount Nowa Nowa Sediments. Sedimentary rocks are exposed along the Mt. Nowa Nowa track for a short distance, but are mainly confined to the valleys of a number of tributaries near the head of Ironstone Creek, being in general at a lower level than the adjacent volcanic rocks. Uphill from the foot of Mt. Nowa Nowa on the east side, the following sequence is observed : sandstones and shales, porphyroids, rhyodacites, andesite ash.

Along Junction Creek, there is an alternation of sandstone, quartzites, shales, tuffs, rhyodacites, andesite ash, and a coarser grained fragmental rock with quartz phenocrysts and micaceous sandstone inclusions. A typical rock type is red micaceous sandstone with large flakes of mica. In thin section (6463) it shows angular to sub-angular quartz grains, brown biotite and occasional grains of plagioclase felspar. The material is in general poorly sorted and it apparently represents a shallow water deposit formed from the disintegration of nearby igneous rocks. Brown, green and white quartzites and brown shales also occur. The green quartzite (6466) consists of larger rounded quartz grains, abundant chlorite and secondary amphibole and a little zircon and plagioclase. The refractive index of the felspar is less than that of quartz, so it is oligoclase or albite. Some quartz is granulated and some shows strain.

There are also a number of variously coloured sandstones, whose appearance suggests a tuffaceous origin.

Middle Devonian

Massive fossiliferous limestones and calcareous shales of proven Middle Devonian age, the ' Buchan Limestones,' outcrop in the valley of Tara Creek, in the northern part of the area, striking approximately N30°E and dipping west. The contacts of limestone and ash beds, and limestone and Ordovician have been mapped. To the west of the Buchan Road, about four miles south of Buchan, there is a smaller limestone outcrop where the rock is being quarried and crushed. A small inlier of limestone occurs south of the main mass in Tara Creek. Strikes and dips recorded in this occurrence suggest it is a fault inlier. Inliers of limestone also occur partly buried by Cainozoic sands and gravels in the side of the Buchan Road just north of Canni Creek and in the valley of Yellow Water Holes Creek.

Cainozoic

Both marine and fluviatile Cainozoic deposits occur in the area, the dividing line, according to Teale (1920) being just south of Nowa Nowa and running east-west.

Marine Sediments

At Nowa Nowa township, the Palaeozoic rocks dip steeply down below stream level and the northern limit of Cainozoic marine sedimentation in this area was probably here. The sediments are horizontally bedded sandy limestones, limestones and marls, which are in part ferruginous. Teale suggested they were probably Janjukian in age.

Fluviatile Deposits

Extending north-east and north-west from Nowa Nowa a thick cover of sands, gravels, ferruginous grits and conglomerates obscure the older rocks of the area and rise up to heights of about 600 ft. above sea level. The heavy fluviatile conglomerates contain large rounded pebbles of reef quartz, jasper and various volcanic rocks. Similar deposits are found in a basin north of Canni Creek, and probably form part of the Torrent Gravels, which are widespread over the plains of East Gippsland. They are regarded by Hills (1940) as having resulted from the erosion of the Eastern Highlands due to uplift in early Pliocene times. The movement evidently continued after deposition of the gravels, as indicated by their present elevation.

Basalt

A small occurrence of basalt on the west side of the South Buchan Road, about four miles south of Buchan, was first recorded by Teale. Hills (1939) showed the rock to be a serpentinized olivine basalt and suggested that the outcrop represents a remnant of a former larger flow. Evidence of age is indefinite, but Hills regards this rock, together with the olivine basalts of the Gelantipy district to the north, as probably Pliocene in age, being younger than the Miocene Older Volcanics of South Gippsland, but older than the Pleistocene basalt of Morass Creek, just north of Benambra. Hills also described decomposed basic flows interbedded with gravels from a road cutting a few miles south of Buchan.

Dykes

A number of decomposed acid dykes, intruding Cainozoic sands and gravels are observed in a road cutting about three miles south of Buchan. Decomposed basic dykes intersect Middle Devonian limestones in the quarry west of the Buchan Road. Hills (1939) also mentions another ' thoroughly decomposed basic dyke ' cutting the Pliocene Torrent Gravels south of Buchan. The basic dykes are therefore all probably Upper Cainozoic in age. At one locality, about three miles SSW of Mt. Tara, near a rhyodacite-Ordovician contact, a fairly fresh dolerite dyke occurs. It is a green, even-grained rock, consisting of plagioclase laths (andesine to labradorite), colourless augite, and magnetite. Secondary minerals are calcite, chlorite, epidote, and rare clinozoisite.

Mineralization

A widespread and varied mineralization is found throughout the area in the Palaeozoic rocks. No systematic study has been made of the ore deposits, and they would appear to offer an interesting field for future research. Generally, the deposits are of limited extent, and though various gold, copper, iron, manganese, lead and silver mines have been worked for short intervals in the past, the only one at present operating is the Oxide Mine, about two miles NNW of Mt. Tara, where small amounts of manganese ore, chiefly psilomelane, have been extracted. Mineral localities, which have been recorded in literature, are given below, and the location of the most important of these is indicated on the general map.

Iron and Manganese

Boggy Creek—Mt. Nowa Nowa—' Eight-mile ' : Outcrops of manganiferous specular hematite associated with red jaspers and quartz showing colloform banding are common along Lower Boggy Creek and south of Mt. Nowa Nowa. The ' Eight Mile ' lode, consisting of more massive hematite, is the most important deposit in the area. These occurrences appear to have resulted from replacement by hydrothermal solutions, but their extent in depth is unknown. Teale (1920), Whitelaw (1920), Howitt (1925).

Iron Mask Lode. This formation, north east of Canni Creek, outcrops over a distance of about 1,000 ft. with an average width of 30 ft., and is composed of hematite, limonite and manganiferous iron ore. Dunn (1907C), Whitelaw (1920).

Oxide Mine. Ferruginous manganese ores assaying up to 40% manganese outcrop in the volcanic beds north of Mt. Tara. Kenny (1925). One such deposit is at present being worked at the Oxide Mine, where the ore-body appears to occupy a fault.

Tara Creek. Map 2 shows an area of ironstone in limestone country near the head of Tara Creek. The deposit consists of hematite and cellular limonite, and may represent the gossan of a sulphide ore body.

Gold

The chief gold-bearing area is in faulted and disturbed Ordovician, south of Lady Torr Creek, where small rich reefs containing fine gold associated with chalcopyrite have been worked. Gold also occurs in minor amounts at several localities west of Mt. Tara, including Tara Crown. Dunn (1907A). Alluvial gold has been reported from Tara Creek by Howitt (1876).

Lead-Silver

Tara Crown. Five miles south-east of Buchan is the Tara Crown lode, which was first worked for gold and later for lead and silver—Whitelaw (1921). The lode occupies a fault which strikes NNE through the volcanic rocks and appears to extend to the Oxide Mine.

Back Creek. North of Mt. Tara, along Back Creek, argentiferous galena veins are found in the limestone associated with copper ores and occasionally zinc blende—Howitt (1876), Whitelaw (1921).

COPPER

The only copper deposit of any size was at the Dominion Copper Mine near the headwaters of Hospital Creek—Dunn (1907B).

BARYTES

Several small barytes deposits outcrop in the hills around Canni Creek, west of the Buchan Road (Teale, 1920). The mineral is also found as a small body just south of the Iron Mask Mine (Dunn, 1907C) and as small veins along Boggy Creek and south of Mt. Tara.

Heavy Minerals

Heavy mineral analyses have been made on the rocks listed in Table 2, which also includes analyses made by G. Baker (1941) on other granitic rocks in south-east Gippsland. The most striking feature of the work is the occurrence of anatase in all the north Tara Range rocks except the granite, and in the Bete Bolong quartz syenite. The blue variety occurs in all these rocks, and is accompanied by the yellow variety in the Tara Range andesite and syenite. In the latter rock, the yellow form is the more prevalent. In over one hundred Victorian igneous rocks examined by Baker (1941), anatase was found in only six. However, as will be shown later, the anatase is probably of secondary origin, and its occurrence cannot be used to indicate that the rocks in which it is found are comagmatic.

Despite an appreciable difference in their index numbers, there is a great similarity in the heavy mineral assemblages of both the Tara Ranges and Bete Bolong quartz syenites, which provides extra evidence in favour of Teale's suggestion that the two outcrops form part of the one plutonic body.

Petrogenesis

Two features of the petrology of the area are the diversity of igneous rock types and the widespread development of secondary minerals.

ORIGIN OF THE VOLCANIC ROCKS

The Snowy River Series covers an area of some 1000 square miles in Victoria and reaches thicknesses of up to 2500 ft. It consists largely of accumulations of volcanic and pyroclastic materials with occasional sedimentary interpolations. Even in the small area covered by the authors, a wide variety of acid and intermediate igneous rocks is encountered. Oligoclase rhyodacites and quartz andesites are the commonest volcanic types, but quartz keratophyres, tuffs of all grain size, dacitic and trachytic varieties also occur. Frequent inclusions, consisting of sanidine laths in a glassy ground mass, in the rhyodacites and ash beds, indicate the earlier presence of more widespread trachyte flows than are now found. Generally individual flows appear to have been of limited extent, and an alternation of acid, intermediate and tuffaceous types frequently occurs, indicating a continually changing set of conditions in the magma chamber. There is thus no evidence of simple differentiation having occurred within the magma chamber before extrusion. Differentiation within individual flows after extrusion is not apparent.

The origin of the igneous rocks presents an interesting problem. It has been proposed that acid lavas may form by pure crystallization differentiation of a femic magma, but in the production of the large volume of acid and intermediate extrusive rocks forming the Snowy River Series, an even greater quantity of basaltic magma should have been formed and no indication of this is seen at the surface. Holmes (1931) has suggested that the trend of normal crystallization differentiation of a basaltic magma is towards trachytic types

TABLE 2.—TABLE OF HEAVY MINERAL INDICES AND ASSEMBLAGES

	Anatase	Apatite	Augite	Biotite	Chlorite	Epidote	Fluorite	Garnet	Hematite	Horneblende	Hypersthene	Ilmenite	Limonite	Magnetite	Rutile	Sphene	Sulphides	Tourmaline	White Mica	Zircon—colourless	Zircon—with inclusions	Zircon—pale yellow	Zircon—zoned	Zircon—torpedo	Ziosite	Index Number
1. Granite, Tare Range	o			V	c				c				c				r			V		r		V		·31
2. Quartz Syenite, Tara Range	r	c			r	c				A				c						o						11·20
3. Rhyodacites, North Tara Range	X			H						X				H		H				X						·16
4. Rhyodacites, South Tara Range		r										r														·12
5. Andesite, North Tara Range	c	o			r	V			r	c							a						V			·11
6. Rhyodacite-Syenite Contact, Tara Range	X				X	X				X					X					X		X		X		
7. Granite, Bete Bolong		r				c							r								V	r				1·22
8. Quartz Syenite, Bete Bolong	r	c			r	r				A										o				V		17·13
9. Hornblende Granite, Whiskey Creek, Buchan ..		o				o				A										o		r	V	r		14·09
10. Quartz Diorite, Whiskey Creek, Buchan		o	o	A						a	A			A												26·90
11. Devonian Micaceous Sandstone, Tara Range																		o	c							
12. Ordovician Micaceous Sandstone, Tara Range ..	V	V																o	c	r						
13. Granite, Bairnsdale		V		V				o	o			o	c						c	o	c	o	o			0·56
14. Grey Granite, Colquhoun		V		V	c	o			V					V	V		V		c	r	o	V	V			1·07
15. Pink Granite, Colquhoun		V		V	a	c	o		r	V				o					o	V	o	V	V			1·76
16. Granite, Cape Everard		o		A	r							V	o					V	c	o	o	r				3·10
17. Granite, Gabo Island		o		r	o	c	V	o		o				a						c	o					5·78
18. Granodiorite, Orbost		c		A	o	r				c			o				o	o	V	o	o		V	r		11·26
19. Granodiorite, Mt. Drummer		o		a	o	a				A		V		a			o	o	o	o	o					14·59
20. Granodiorite, Mt. Baldhead		o		A	r	o				a				a			o	r	r	o	o	V	V			15·33

A = very abundant a = abundant C = common o = occasional r = rare V = very rare
X = relative amount not determined H = recorded in thin section only
Nos. 1—12 : Specific Gravity of Heavy Liquid = 2·89. Analysts : G. Cochrane, H. Sampson.
Nos. 13—20 : Specific Gravity of Heavy Liquid = 2·88. Analyst : G. Baker.

and that rhyolites are produced when cupolas from the trachytic magma rise up from the underlying basaltic magma in the sial and melt some of the granitic material. This could account for the association of acid and intermediate types in the Snowy River Series, although it would be necessary to have a meridional cupola extending for several hundred miles.

A third possibility is suggested by the paper by A. B. Edwards (1937) on the presence of a quartz diorite magma in Eastern Victoria. To account for the frequent close association of acid, intermediate and basic igneous rocks in this area, all of which contain free quartz, Edwards proposes that they crystallized from a common parent magma, wich was formed by the large-scale assimilation of argillaceous sediments by a tholeiitic magma. It is possible the parent magma of the Snowy River Series formed by a similar process, for all the plutonic and volcanic types contain free quartz (e.g. quartz syenite, quartz andesites, rhyolites, quartz keratophyre), but there is no strong evidence for the removal of large quantities of sediments in the area nor indications from the lavas and plutonic bodies of their large-scale assimilation. The pyroclastics and some of the lavas of the Tara Range contain numerous included fragments but they are mainly of andesite and trachytes. Only in the coarser ashes are shale fragments found and these probably represent pieces caught up in the magma as it broke through to the surface. Partly digested inclusions are rare, so if the quartz diorite formed by assimilation of aluminous sediments, the process must have been deep-seated and complete.

Origin of the Plutonic Rocks

Quartz Syenite. There are three possibilities for the origin of the quartz syenite.

(i) It may have crystallized from a cupola developed from an underlying magma reservoir which intruded during orogenesis.
(ii) It may be derived from the same magma as the volcanic rocks and represent a small pocket of magma which was cut off by closing of the vents after the extrusion of most of the material to give the lavas and tuffs.
(iii) It may be of replacement origin.

The occurrence of three sets of joints suggests solidification from a molten mass thus supporting the magmatic theories. Teale evidently favoured the first hypothesis, for he tentatively correlated the Tara Range ' hornblende granite ' with a similar rock at Bete Bolong and with the granites of Colquhoun and Gabo Island. The Tara Range and Bete Bolong syenites show strong resemblances and are probably related, but microscopically and in their heavy mineral assemblages there is no obvious reason for grouping them with the other granitic rocks as Teale suggested.

It is possible that the quartz syenite formed as a result of the closing of a vent after the extrusion of one of the flows of the Snowy River Series and the subsequent crystallization of the magma thus trapped below the surface. However there does not appear to be any similarity between the chemical analyses of the quartz syenite and those of any of the volcanic rocks which have been analysed. Moreover, the evidence provided by field relations, although not decisive, suggests the quartz syenite being older than the volcanic series. If the former then, is magmatic in origin, it would seem likely that it crystallized from a deep-seated intrusion into the Ordovician sediments. Other hornblende-rich acid plutonic rocks, occur at Whisky Creek, North Buchan, and higher up the Snowy River Gorge. When further work is done on these rocks it may show that they belong to the same petrographic province as the

Bete Bolong and Tara Range syenites and probably throw more light on their age relative to the Snowy River Series.

The third possibility, that the quartz syenite is of replacement origin is improbable since there is no wide range of intermediate types between the Ordovician sediments and the quartz syenite and no possible source for the requisite emanations is known in the district.

Soda Granite and Pegmatite

In Granite Creek, there are veins of oligoclase granite, albite granite and soda pegmatite, which may be either of magmatic or partly or wholly of replacement origin. The presence of chessboard albite and rare myrmekite in the albite granite and pegmatite is fairly conclusive evidence for their formation by replacement. The replaced rock was probably quartz syenite, although the pegmatite may have been formed by metasomatic alteration of the potash felspar in the adjacent aplite.

The evidence for a similar origin of the oligoclase granite is not conclusive. Specimen S 15 (6444) contains 4·12% Na_2O, but the felspars are all altered, and there is no indication of soda replacement. Specimen Q 28 (6427) is similar macroscopically, but in thin section shows abundant chess-board albite attacking quartz and orthoclase. This rock passes by transition into quartz syenite, and it is possible that the S 15 type represents a late stage intrusion of soda-rich magma along favourable planes in the quartz-syenite. Later replacement by soda solutions gave the Q 28 type.

The formation of an albite granite by metasomatic alteration of an intermediate plutonic rock has been described from near Sparta in Oregon, U.S.A., by J. Gilluly (1933), and it is interesting to compare the features of these rocks with those of the Tara Range types. Gilluly attributes the formation of the albite granite to a late-stage and post-magmatic replacement of an almost completely solidified quartz diorite by solutions derived probably by filter-pressing of the lower portion of the same mass. Points of similarity with the Tara Range soda granites are the occurrence of replacement albite (sometimes being the chess-board variety at Sparta) ; the decrease in the amount of dark minerals and accessories as compared with the adjacent intermediate types ; the presence of myrmekite and micrographic textures, and the notable drop in the mafic content of specimens in which micrographic textures occur as compared with the normal granitic rocks. In the field Gilluly has traced a complete transition from albite granite to quartz diorite, indicating the differences in their composition arose in situ. Whether the replacing soda solutions in the Granite Creek rocks are of similar origin to those at Sparta will be discussed in the next section on secondary minerals.

Secondary Minerals

In many of the igneous and sedimentary rocks of the area, there has been an extensive development of secondary minerals—chiefly chlorite (pennine in greater amounts than clinochlore), amphibole, epidote, sericite, and occasionally anatase, sphene and muscovite, together with the introduction of albite and quartz. In some cases, a simple recrystallization has taken place, as seen by the frequent pseudomorphous replacement of pyroxene by secondary amphibole, but usually, as indicated by the presence of amphibole and chlorite in Devonian quartzite and the common association of amphibole with plagioclase, the changes have been brought about by the introduction of active solutions. The problem arises whether these solutions have been brought from the depths or whether they were mobilized within the igneous rocks after their extrusion.

Lime, Iron, Magnesia : The second possibility probably explains the origin of the solutions carrying lime, magnesia and iron. The formation of secondary ferromagnesian minerals is common and widespread in many rocks in Eastern Gippsland. In the Nowa Nowa there is generally a more or less complete breakdown of primary pyroxenes and amphiboles giving pennine and clinochlore and involving a large scale removal of calcium and some iron. Rarely epidote is found pseudomorphous after primary femic minerals, indicating that magnesium has gone into solution. The fact that they are so widely dispersed, together with the indications that lime, magnesium and iron have been removed from primary minerals, favours the hypothesis that the secondary ferromagnesian minerals were deposited from active solutions which were probably formed by ground waters dissolving out certain elements from the minerals of the volcanic rocks and redepositing them elsewhere to form new minerals, the channels being provided by the various major and minor fractures produced during the era of compression, shear and warping, which gave rise to the porphyroids.

Potash : The sericite occurring in the Boggy Creek ' diabase ' probably derived its potash from similar solutions.

Titania : The biotite of the Tara Range rhyodacite is evidently a titaniferous variety, for in several sections it is seen partially broken down to muscovite, chlorite and sphene. Anatase has been found in the heavy mineral assemblages of several of the Tara Range rocks. As A. Brammall and H. Harwood (1923) have pointed out, this mineral may be of pneumotolytic or hydrothermal origin. It is unlikely that the anatase of the Tara Range rocks is of pneumatolytic origin since there is an absence of other typical pneumatolytic minerals such as tourmaline or topaz. Numerous examples, however, have been described of anatase having formed by the hydrothermal breakdown of sphene, ilmenite and rarely titaniferous biotite and magnetite. It therefore seems probable that the titania for the Tara Range anatase was derived originally from the titaniferous biotite. Hydrothermal solutions probably decomposed some of the biotite, or the sphene associated with it, and carried away titania, depositing it in other rocks as anatase.

Soda : The occurrence of chessboard albite and rarely myrmekite in the Tara Range soda granites and pegmatite indicates secondary replacement by soda in these rocks. Elsewhere albite is found in replacement coronas and rims replacing quartz phenocrysts in some rhyodacites which have been examined. There are also quartz–albite veinlets intruding volcanic rocks, notably the southern andesites. The problem presents itself whether the introduction of all these soda-rich solutions occurred at the same time and from where they originated.

Though there are outcrops of quartz keratophyre in the area containing up to 7% Na_2O, the limited occurrence of the albite veins and albitized rocks and the comparatively large distance between the latter and the nearest keratophyres, indicates that soda was evidently not carried by active ground water solutions like the lime, etc., but that more probably the replacement soda minerals are of direct magmatic origin. The quartz keratophyres are among the youngest of the volcanic rocks and appear to represent an end-stage magmatic product, when there was a relative enrichment of soda as compared with potash. At the end of vulcanicity, there was evidently a small amount of soda and silica left, which was driven out into the overlying rock giving the quartz-albite veinlets. The presence of clinochlore in some quartz-albite veinlets where it is distinct from the scattered pennine flakes in the rocks, which these veins intrude, points to minor amounts of iron and magnesium in secondary femic minerals being of deep-seated origin. The albite rims in the rhyodacite also probably represent a late-stage soda attack by residual liquors.

There still remains the question of the soda-solutions, which brought about albitization of the plutonic rocks in Granite Creek. The fact that the quartz syenite and soda granite very closely attain the same height points to their having been eroded to the same level before extrusion of the volcanics. Otherwise it would not be unreasonable to expect that the albite replacement would extend into the overlying rocks. Therefore the soda and silica introductions which produced the albite granite (S 6, Q 28) and the pegmatite may have intruded close after the crystallization of the oligoclase granite (S 15). The other possibility which cannot be disproved is that these soda-silica solutions are related to late-stage soda enrichment of the volcanic magma and that on traversing the plutonic rocks they brought about albitization, whilst in the overlying rhyodacites, which were still possibly at a fairly high temperature, the soda attack was directed at the quartz phenocrysts and resulted in the formation of albite rims.

Conclusion

In the absence of conclusive evidence it is deduced that the quartz syenite is older than the volcanic series. Though the possibility of its having a replacement origin should not completely be neglected, the simplest and most probable explanation of its formation is that it crystallized from an intrusive magma. It is possible that it is the southernmost outcrop of a batholith which extends northwards along the Snowy River. The oligoclase granite represents a soda-rich differentiate of this same magme, but the age of the albite granites and pegmatite, which formed by replacement processes, remains uncertain. They may have been produced at the same time as the soda solutions attacking the rhyodacites and therefore be possibly related to the keratophyre magma.

Structural Features

Relations of Lower Devonian and Upper Ordovician

North-South Ordovician Belt

The appearance of the outcrop, which is elongated roughly in the direction of the chief trend-line of the area, suggests the existence of boundary faults, the rocks themselves being faulted and, in parts, brecciated and sheared. These features are especially noticeable in the northern area, in the vicinity of Lady Torr Creek, where extremely variable strikes are observed. The general contortion and disturbed nature of the strata are suggestive of contact faults.

A small area north of Lady Torr Creek, where contacts between Middle Devonian, Lower Devonian and Ordovician were observed, was examined in order to ascertain whether the occurrence of Middle Devonian limestones adjacent to Ordovician rocks was indicative of faulting (Map 2). A considerable thickness of ash-beds, which here constitute the top of the Lower Devonian series, cut out very suddenly to the south, and do not appear between the small limestone outlier and the Ordovician basement. A fault contact, running north of west between the Lower Devonian and the Upper Ordovician is therefore indicated. The small area of limestone itself is regarded as resting unconformably on the Upper Ordovician, a relationship which implies the existence of the above-mentioned fault before the deposition of the limestone. Section B, drawn E-W, is a diagrammatic representation of the relations of the volcanic series to the basement rocks. On the eastern side, basal tuffs and sandstones containing marine fossils are shown resting unconformably on the Upper Ordovician, striking NE and dipping west. These are immediately overlain by the massive rhyodacites and andesitic rocks of the Tara Ranges. The straight line boundary of these rocks up against the Ordovician belt indicates a steeply-dipping contact, possibly a faulted syncline. Further south, where the flows are observed to dip off the Ordovician, the line of contact is extremely irregular. A relatively thin sheet of lavas is depicted, overlying an uneven Ordovician basement, portions of which occasionally project through as inliers.

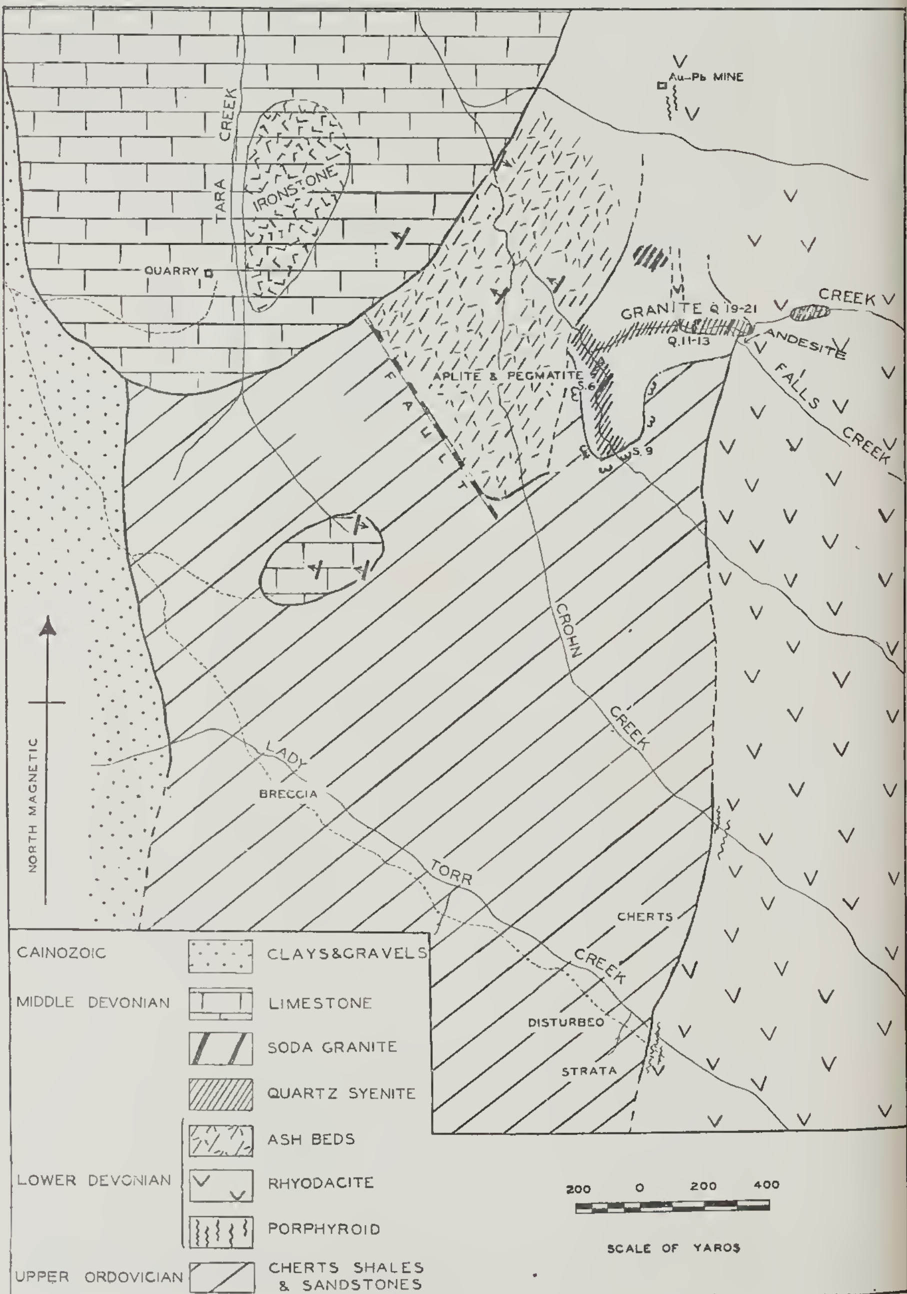

Fig. 2.

In the Grap Creek area, the sediments consist of sandstones quartzites and black slates. Strikes vary, but are predominantly N30°E and the rocks dip east at 45°-50°. It is worthy of note that certain elongated outcrops of igneous rocks occur whose relations to topography suggest steeply dipping contacts. These may possibly represent composite intrusions.

Lower Devonian

Available dips in the volcanic rocks in the area west of the Ordovician belt indicate that the structure is dominantly synclinal. At Nowa Nowa, porphyroids of the Boggy Creek Group dip off the Ordovician, while in the north, quartz-andesites form the basal rocks of the series. Between these limits, an area of rhyodacites and associated sedimentary rocks is exposed, the succession observed at Mt. Nowa Nowa being : (1) sandstones and shales (mainly Ordovician), (2) rhyodacites, and overlying these (3) quartz-andesites. At their contacts with these sedimentary rocks as well as those further east the rhyodacites are converted to porphyroids. The occurrence of porphyroids at sandstone-rhyodacite contacts is also noted at Tomato Creek, and north of Grap Creek.

The general structural picture provided by this area then is one of disharmonic folding within the heterogeneous Lower Devonian series, each member of which has been subjected to the same orogenic forces, but the effects produced in it are according to its physical nature. The behaviour of the various structural units may be summarized as follows :

1. Massive Rhyodacites : The resistance to folding causes a certain amount of overriding and minor shearing movements within the flows, giving rise to porphyroids.
2. Andesitic Rocks : Members of the andesitic suite, dominantly quartz-andesites, are in general more capable of folding than the brittle rhyodacites. This is partly due to the relatively smaller percentage of quartz, both secondary and as phenocrysts, which they contain, and also to the relative abundance of softer fragmental beds. Consequently rocks of this type do not in general give rise to porphyroids. At one locality only, the Ordovician contact south of Canni Creek, a quartz-rich andesite was observed showing a certain degree of schistosity. Andesitic types represented in the Boggy Creek Series are noticeably less sheared than the typical porphyroids, in which large quartz phenocrysts are characteristic.
3. Boggy Creek Beds : This series, consisting chiefly of thinly bedded pyroclastics, is sandwiched between the Ordovician basement and andesitic rocks. Movement of the overlying mass has sheared the incompetent tuffs up against the Ordovician (see under Porphyroids).

The succession in the Lower Devonian as observed in the northern Tara Range and around Mt. Tara is distinct from that further south, at Nowa Nowa.

Porphyroids

Field evidence indicates that, in general, the occurrence of schistose porphyroids is not related to zones of thrust faulting or any major fault displacement. Schistosity appears to have been produced by movements within the series of volcanics, sediments and pryoclastics.

There are two distinct types of sheared volcanic rocks to which the term ' porphyroid ' has been applied. The first, typified by the porphyroids associated with the Mt. Nowa Nowa sandstones and shales, are developed directly from massive rhyodacites, and are confined to the contacts of these flows with the sedimentary rocks which underlie them. The porphyroids have evidently been produced by intraformational shearing in the brittle acid volcanics, when subjected to the compressive stresses which threw the underlying Devonian sediments into fairly sharp folds.

The second type of porphyroid has developed from the thinly bedded lavas and tuffs, which are in part sub-aqueous, of the Boggy Creek series. The shearing of these incompetent beds has probably originated in essentially the same way as that producing the ' rhyodacite-porphyroids.'

The possibility of a fault contact between these porphyroids and the Ordovician must be recognised. Teale (1920) gives a small sketch map of the contact in Boggy Creek, showing crumpled and contorted Ordovican rocks. The amount of distortion of the strata was found to be even greater than that shown in the sketch, and the line of contact, which trends south of west in Boggy Creek may represent a fault. On the other hand, the relationships of the Boggy Creek series are significant, being placed between a considerable thickness of overlying andesitic lavas, and the solid Ordovician basement. On compression any slight overriding movement of the volcanic flows would exert strong shearing stresses on the small thickness of incompetent beds between the two resistant masses, producing porphyroids in the Boggy Creek series. Certain of the basal flows of the andesitic suite have been affected by the same movement ; a specimen of the less massive diabase exhibits the porphyroid microstructure in thin section.

Minor occurrences of porphyroids in the Tara Ranges are found at Ordovician-rhyodacite contacts, probably caused by shear movements in the rocks at places where the lava sheet is thinner, and at Gunn's mine, where porphyroids are developed in the footwall of a fault ; this is the only instance seen of porphyroids being produced by faulting.

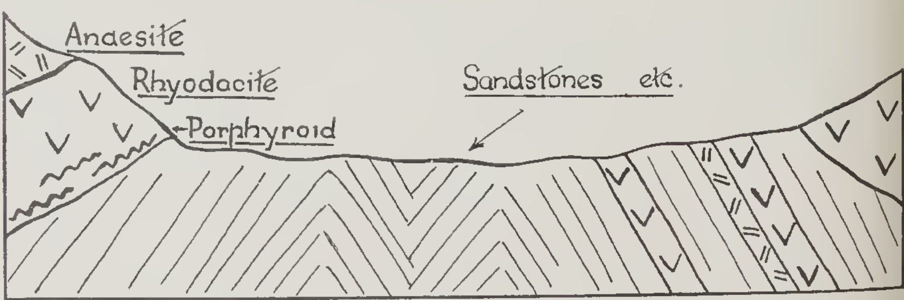

Fig. 3. Section A.

Fig. 4. Section B. Generalized Section E-W through the Ordovician Belt

Summary and Conclusions

A petrological examination of the rocks of the Snowy River Series in the Nowa Nowa-Mount Tara area has been carried out, extending the work of Teale (1920). In certain key areas the distribution of the various igneous rock types has been mapped in detail. Additional outcrops of the Ordovician rocks have been discovered, and the area of sedimentary rocks NE of Mt. Nowa Nowa, recorded as Ordovician by O. A. L. Whitelaw (1920), has been examined. The occurrence of porphyroids around the periphery of this belt was noted.

Sediments of definite Lower Devonian age are described from the Boggy Creek area, where sandstone beds are associated with thinly-bedded sheared tuffs and lavas, and from the area south of Mt. Tara, where tuffaceous sandstones, containing fossils of probable Lower Devonian age underlie massive rhyodacites and constitute the base of the series.

Relations of the volcanic and pyroclastic rocks to basement Upper Ordovician are in the main unconformable, though in several cases the existence of possible faults is noted. Schistose porphyroids occur at the contacts of volcanic rocks with sediments of Upper Ordovician and Lower Devonian age. They attain their greatest development in Boggy and Ironstone Creeks, where sheared tuffs, lavas and sediments occur, and around the perimeter of the Mount Nowa Nowa sandstones, where gradations to unaltered massive rhyodacites are observed. It appears fairly clear, that shearing movements producing the porphyroids are not associated with major faulting, but have rather resulted from overriding movements of brittle massive lavas at or near the base of the series.

A small granitoid complex, consisting of quartz syenite, soda granite, albite granite, pegmatite and aplite is described from Granite Creek, Tara Range. Evidence is presented indicating that the plutonic rocks are definitely younger than the Upper Ordovician. From an examination of certain contact rocks, it appears that small-scale granitization of rhyodacite has occurred, i.e. the soda granite is younger than the rhyodacites.

Subsequent hyrdothermal activity has caused extensive solution and recrystallization of earlier minerals, and the deposition of secondary minerals, the principal elements involved being Ca, Mg, and Fe, and to a lesser extent Ti.

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Description of Plates

PLATE IX

Fig. 1. Silicified ash bed showing minor faulting. Porphyroid Series, Ironstone Creek. G24, ×1 3/5.
Fig. 2. Sheared shaly ash bed. Lower Boggy Creek. K9, ×2.
Fig. 3. Granitized rhyodacite showing banding and schlieren of granitic material. Granite Creek. S16, natural size.

PLATE X

Fig. 1. 'Chess-board' albite in pegmatite. Granite Creek South. (6432), crossed nicols, ×30.
Fig. 2. Albite granite with granophyric structure and 'chess-board' albite replacing quartz. Granite Creek South. (6435), crossed nicols, ×23.
Fig. 3. Granitized quartzite showing quartz grains (Q), albite (A) replacing quartz, orthoclase (Or), zircon (Z) and chlorite (Cl). Granite Creek South. (6437), crossed nicols, ×110.
Fig. 4. Granitized rhyodacite showing development of quartz, orthiclase, plagioclase and hornblende (right). (6421), crossed nicols, ×30.

PLATE XI

Fig. 1. Diabase showing idiomorphic augite phenocryst, quartz, altered felspar and chlorite. Lower Boggy Creek. (6361), ordinary light, ×30.
Fig. 2. Silicified ash bed showing banding indicative of probable subaqueous deposition. Boggy Creek. (6400), ordinary light, ×5.
Fig. 3. Ash bed showing fragmental texture. Ironstone Creek. (6343), ordinary light, ×12½.
Fig. 4. Porphyroid showing fractured quartz phenocryst and sericite strands. Ironstone Creek. (6335), crossed nicols, ×30.